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NATIONAL DAM SAFETY PROGRAM. NO NAME 165 (CRYSTAL LAKE DAM) (MO--ETC(U)
JUL 78 P R ZAMAN, B A AINSWORTH, H L CALLAHAN DACW43-78-C-0148

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MISSOURI-KANSAS CITY BASIN

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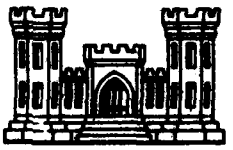
AD A106842

NO NAME 165
(CRYSTAL LAKE)
JACKSON COUNTY, MISSOURI
MO. 10580

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM



PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

JULY 1978

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A107542
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Phase I Dam Inspection Report National Dam Safety Program MONONAME 165 (MO 10580) Ray County, Missouri	5. TYPE OF REPORT & PERIOD COVERED Final Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Black & Veatch, Consulting Engineers	8. CONTRACT OR GRANT NUMBER(s) DACW43-78-C-0148
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101	12. REPORT DATE Jul[illegible]978
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18. SUPPLEMENTARY NOTES

Paul R. /Zaman Bruce A. /Ainsworth
Harry L. /Callahan

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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MISSOURI-KANSAS CITY BASIN

NO NAME 165
(CRYSTAL LAKE)
JACKSON COUNTY, MISSOURI
MO. 10580

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

JULY 1978

SUBJECT: No Name 165 (Crystal Lake) Dam Phase I Inspection Report

This report presents the results of field inspection and evaluation of the No Name 165 (Crystal Lake) Dam. It was prepared under the National Program of Inspection of Non-Federal Dams.

SUBMITTED BY: SIGNED
Chief, Engineering Division

20 SEP 1978
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer

20 SEP 1978
Date

NO NAME 165
(CRYSTAL LAKE DAM)

RAY COUNTY, MISSOURI

MISSOURI INVENTORY NO. 10580

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

BLACK & VEATCH
CONSULTING ENGINEERS
KANSAS CITY, MISSOURI

UNDER DIRECTION OF

ST. LOUIS DISTRICT, CORPS OF ENGINEERS

FOR

GOVERNOR OF MISSOURI

July 1978

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	No Name 165 (Crystal Lake Dam)
State Located	Missouri
County Located	Ray County
Stream	East Fork of Fishing River
Date of Inspection	26 July 1978

Crystal Lake Dam was inspected by a team of engineers from Black & Veatch, Consulting Engineers for the St. Louis District, Corps of Engineers. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers and developed with the help of several Federal and State agencies, professional engineering organizations, and private engineers. Based on these guidelines, this dam is classified as an intermediate size dam with a high downstream hazard potential. According to the St. Louis District, Corps of Engineers the estimated damage zone extends 8 miles downstream of the dam. Within the first 1.5 miles downstream of the dam are 4 homes and 2 improved road bridges. The damage zone runs through Excelsior Springs, Missouri (population 9,500). The City of Excelsior Springs is approximately 1.5 miles downstream of the dam.

Our inspection and evaluation indicates the spillway does meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. The spillway will pass the probable maximum flood without overtopping. It should be noted that a flood of this magnitude would inundate major portions of Excelsior Springs, Missouri as indicated in the Flood Insurance Study for Excelsior Springs, Missouri, U.S. Department of Housing and Urban Development, Federal Insurance Administration.

Deficiencies visually observed by the inspection team were erosion, seepage, and presence of excessive brush and small trees on the downstream embankment slope. Although an inspection of Lake Arrowhead was not made, the inspection team observed an erosion ditch forming at the toe of Lake Arrowhead dam. Erosion is the result of spillway discharges. Seepage and stability analyses were not available for this dam. In accordance with the "Recommended Guidelines for Safety Inspection of Dams" seepage and stability analyses should be on file for dams in the High Hazard classification.

There were no observed deficiencies or conditions existing at the time of the inspection which indicated an immediate safety hazard. Future corrective action and regular maintenance will be required to prevent additional vegetal growth on the embankment which could lead to the development of potential safety hazards. A detailed report discussing each of these deficiencies is attached for submittal to lake owners and to the Governor of Missouri.

Paul R. Zaman
Paul R. Zaman, PE
Illinois 62-29261

Bruce A. Ainsworth
Bruce A. Ainsworth, PE
Missouri E-18023

Harry L. Callahan
Harry L. Callahan, Partner
Black & Veatch

OVERVIEW OF DAM (LOOKING SOUTH)

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
NO NAME 165 - (CRYSTAL LAKE DAM)

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SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the District Engineer of the St. Louis District, Corps of Engineers, directed that a safety inspection of the No Name 165 (Crystal Lake Dam) be made.

b. Purpose of Inspection. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

c. Evaluation Criteria. Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed with the help of several Federal and State agencies, professional engineering organizations, and private engineers.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The dam is an earth structure located in the valley of the East Fork of Fishing River in west-central Ray County, Missouri (see Plate 1). A roadway has been constructed across the top of the dam. Topography of the contributing watershed is characterized by rolling hills. Land use consists of residential areas and farm land. Topography in the vicinity of the dam is shown on Plate 2. Lake Arrowhead and Timber Lake are located in the Crystal Lake watershed as shown on the Vicinity-Topography Map.

(2) A spillway channel was excavated within the limestone strata in the south abutment. A concrete broad-crested weir was constructed upstream from the south extension of the dam axis with the limestone cut serving as the discharge channel.

(3) An outlet structure is located approximately 160 feet upstream from the centerline of the dam near the north abutment. A manually operated sluice gate is located on a berm at the structure.

(4) A gravel drain was constructed at the downstream toe of the embankment with a one foot diameter discharge pipe extending from the drain.

(5) Pertinent physical data are given in paragraph 1.3.

b. Location. The dam is located in the west-central portion of Ray County, Missouri, as indicated on Plate 1. The lake formed by the dam is shown on the United States Geological Survey 7.5 minute series quadrangle map for Excelsior Springs, Missouri in Sections 29 and 32, T53N, R29W.

c. Size Classification. Criteria for determining the size classification of dams and impoundments are presented in the guidelines referenced in paragraph 1.1c above. Based on these criteria, the dam and impoundment are in the intermediate size category.

d. Hazard Classification. The hazard classification assigned by the Corps of Engineers is as follows: The Crystal Lake Dam has a high hazard potential, meaning that the dam is located where failure may cause loss of life, serious damage to homes, extensive agricultural, industrial and commercial facilities, important public utilities, main highways or railroads. For the Crystal Lake Dam, the flood damage zone extends 8 miles downstream of the dam. Within the first 1.5 miles downstream of the dam are 4 homes and 2 improved road bridges. The damage zone runs through the City of Excelsior Springs, Missouri (population 9,500). Excelsior Springs is approximately 1.5 miles downstream of the dam.

e. Ownership. The dam is owned by Crystal Lake Development Company of Excelsior Springs, Missouri, 9503 E. 63rd St., Room 116, Raytown, Missouri 64133.

f. Purpose of Dam. The dam forms a 100-acre recreational lake.

g. Design and Construction History. The dam was designed by the late E. I. Myers, Consulting Engineer of Kansas City, Missouri in 1969. Construction began in 1969 by Tri-City Construction Company, Kansas City, Missouri under the supervision of Lemuel E. Hutton, Engineering Geologist. Impoundment of water began in 1970.

h. Normal Operating Procedure. Normal rainfall, runoff, transpiration, and evaporation all combine to maintain a relatively stable water surface elevation.

1.3 PERTINENT DATA

a. Drainage Area - 9,900 acres of which approximately 15 percent is in the Lake Arrowhead and Timber Lake drainage areas.

b. Discharge at Damsite.

(1) Normal discharge at the damsite is through an uncontrolled spillway. The water level could be lowered below normal pool elevation by use of the sluice gate (see paragraph 3.1c).

(2) Estimated experienced maximum flood at damsite - unknown.

(3) Estimated ungated spillway capacity at maximum pool elevation -48,800 cfs (top of dam).

c. Elevation (Feet Above M.S.L.).

(1) Top of dam - 871.5 ± (see Plate 3)

(2) Spillway crest - 856.5

(3) Streambed at centerline of dam - 818 ±

(4) Maximum tailwater - unknown.

d. Reservoir. Length of maximum pool - 8,200 feet ±

e. Storage (Acre-feet).

(1) Top of dam - 4,756

(2) Design Surcharge - not available

f. Reservoir Surface (Acres).

(1) Top of dam - 200

(2) Spillway crest - 100

g. Dam.

(1) Type - earth embankment

(2) Length - 1,200 feet

(3) Height - 54 feet maximum

(4) Top width - 40 feet

(5) Side Slopes - (see Plate 5)

(6) Zoning - Composed of impervious core supported by random fill on both faces (see Plate 5)

(7) Impervious Core - Vertically extends throughout the entire height of the dam with a 30-foot top width and 1 to 1 side slopes (see Plate 5).

(8) Cutoff - (see Plate 5)

(9) Grout curtain - unknown

h. Diversion and Regulating Tunnel - none

i. Spillway.

(1) Type - concrete and rock (see paragraph 3.1c)

(2) Length of weir - 300 feet (see paragraph 3.1c)

(3) Crest elevation - 856.5 feet m.s.l.

(4) Gates - none

(5) Upstream Channel - none

(6) Downstream Channel - Broken limestone and shale. Side slopes one mile downstream of dam are typical of streams in the area.

j. Regulating Outlets - 30-inch diameter bituminous coated asbestos bonded corrugated metal pipe with 8-feet square, 12 gage bituminous coated asbestos bonded corrugated metal seepage collars. The spacing and construction method used for installing the seepage collars are unknown. Also with 60-inch diameter gatewell riser, screw gate with riser stem, and gate operating mechanism.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

Design data was made available by Tri-City Construction Company and Lemuel E. Hutton. The data included a report with background design information, as-built drawings (Exhibits from report), and inspection and construction records. Also included were miscellaneous boring logs as submitted by Lemuel E. Hutton. Due to lack of complete logs, no soil information is shown on Plate 4 other than that noted on the as-built drawings.

2.2 CONSTRUCTION

The dam was constructed in 1969 and 1970 by Tri-City Construction Company of Kansas City, Missouri. Some pertinent construction records were obtained from Tri-City Construction. Complete test results of the in-place embankment material as submitted by Lemuel E. Hutton were unavailable.

2.3 OPERATION

The maximum recorded loading on the dam is unknown.

2.4 EVALUATION

a. Availability. Engineering data in the form of background reports, as-built drawings, and construction records were available from Tri-City Construction Company and Lemuel E. Hutton. No other engineering data were found.

b. Adequacy. The engineering data available were inadequate to make a detailed assessment of design, construction, and operation. Seepage and stability analyses are needed to satisfy the requirements of Section 3.6.1 of the guidelines.

c. Validity. The engineering data available were insufficient to determine the validity of the design, construction, and operation.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of Crystal Lake dam was made on 26 July 1978. The inspection team included professional engineers with experience in dam design and construction, hydrologic - hydraulic engineering, and geotechnical engineering. Specific observations are discussed below. No observations were made of the condition of the upstream face of the dam below the pool elevation at the time of the inspection.

b. Dam. The inspection team observed the following items at the dam. Some erosion was noted about 500 feet from the right abutment, 30 feet below the crest of the dam. Dense vegetation more lush than that typical of the embankment was observed at the abutments. This indicates a high soil moisture content which is a probable result of minor seepage. The growth of weeds along the downstream slope should be controlled. The slopes of the dam are not uniform, but are in good shape. Slopes observed were flatter than those indicated on Plate 5 which shows the design section. Apparently excess excavated material was placed on the embankment slopes during construction. Rock has been placed on the upstream slope with no evidence of erosion. No other erosion was observed during the inspection.

c. Appurtenant Structures. The spillway is a concrete broad-crested weir, 300 feet long which spills into a limestone and shale discharge channel. There is seepage along the joint between the road slab and downstream side of the concrete weir. Minor weathering was observed near the vertical cut at the left spillway wall. Seepage of water along the limestone and shale shelf was noted 500 feet downstream of the weir. The gate well riser and operator of the regulating outlet appeared in good condition at the time of inspection. The operator handle was missing; thus, the gate could not be checked for operation. No water was discharging through the outlet culvert at the time of inspection. The gate is an Armco 55-10C with stainless steel stem crank operated CPE-4 pedestal mount lift with cast-iron gate, bronzed faced (Invert El.834.1). The outflow pipe is 340 lineal feet of 30 inch bituminous coated asbestos bonded corrugated metal pipe. The pipe is fitted to a 60 inch gate well riser and the gate. The gate operating mechanism is set at elevation 871.55.

d. Reservoir Area. No slides or excessive erosion due to wave action were observed along the shore of the reservoir.

e. Downstream Channel. Spillway discharge flows over the concrete, broad-crested weir to a cut limestone channel, then to a natural streambed channel. Heavy vegetation and mild slopes typical of streams in the area characterize the area downstream of the spillway. A bridge crossing the downstream channel is located within one mile of the spillway.

3.2 EVALUATION

None of the conditions observed are significant enough to indicate a need for immediate remedial action, however, if erosion, vegetal growth, and seepage continue unchecked, a serious potential for failure will develop.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

Controlled outlet works exist, but have, reportedly, not been used. The pool is primarily controlled by rainfall, runoff, evaporation, and capacity of the uncontrolled spillway.

4.2 MAINTENANCE OF DAM

Maintenance performed was unknown.

4.3 MAINTENANCE OF OPERATING FACILITIES

Apparently, no maintenance has been performed on the gate or gatewell riser.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

The inspection team is not aware of any existing warning system for this dam.

4.5 EVALUATION

Existing seepage observed on the downstream side of the dam, although minor, increases the potential for failure and warrants regular monitoring and control.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. Report and as-built drawings were available. Design calculations were available for hydrology and hydraulics.

The hydrologic and hydraulic calculations were performed by the late E. I. Myers, Consulting Engineer, Kansas City, Missouri. The design runoff as calculated by Mr. Myers was determined using the Rational Formula, Q=CIA. To anticipate future basin conditions a value of "c" was assumed at 0.80 with a 30 minute period of concentration. A peak runoff rate from the drainage basin of 15.60 square miles (10,000 acres) was determined at 100-year frequency of 44,000 cfs with a rainfall intensity of 5.5 inches per hour. The maximum designed lake level (El.866.5) was determined to be 10 feet above the weir crest leaving 5 feet of freeboard. The rate of discharge over the spillway at this level was noted as 29,300 cfs. The discharge when the reservoir would have an elevation equivalent to the top of dam (El.871.5) was noted as 55,800 cfs. Given the geometry of the spillway weir and downstream channel, the rates of discharge from the spillway appear excessive. The design calculations used the broad-crested weir equation:

$$Q = CLH^{1.5}$$

The design "C" values for 10 feet of head on the weir and top of dam were 3.09 and 3.20, respectively. A "C" of 2.8 would be more acceptable placing the discharge at top of dam equal to 48,800 cfs.

b. Experience Data. The drainage area and lake surface area are developed from USGS Excelsior Springs and Lawson Quadrangle Maps. The spillway and dam layout are from surveys made during the inspection and drawings from the background report.

c. Visual Observations.

(1) Concrete weir spillway and the spillway discharge channel are in good condition. Seepage was observed at the joint between the road slab and downstream side of the concrete weir.

(2) Drawdown facilities are available to evacuate the pool, see paragraph 3.1c.

(3) The spillway and exit channel are located at the south abutment. Spillway releases will not endanger the integrity of the dam.

d. Overtopping Potential. The spillway will pass the probable maximum flood, which is the spillway design flood recommended by the guidelines, without overtopping. The probable maximum flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are

reasonably possible in the region. Failure of upstream water impoundments shown on the 1975 revised USGS map would not have a significant impact on the hydrologic or hydraulic analysis as the storage of these reservoirs was not considered. However the effect of total failure of either Lake Arrowhead or Timber Lake dams has not been investigated.

According to the St. Louis District, Corps of Engineers, the effect from rupture of the dam could extend approximately 8 miles downstream of the dam. There are 4 inhabited homes within 1 1/2 miles downstream of the dam which could be severely damaged and lives of the inhabitants could be lost should failure of the dam occur. The City of Excelsior Springs is approximately 1 1/2 miles downstream of the dam.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visual observations of conditions which affect the structural stability of this dam are discussed in Section 3, paragraph 3.1b.

b. Design and Construction Data. No design data relating to the structural stability of the dam were found.

c. Operating Records. No operational records exist.

d. Post Construction Changes. No post construction changes exist which will affect the structural stability of the dam.

e. Seismic Stability. The dam is located in the Seismic Zone 1. However, since stability analyses do not exist no inferences are made to the seismic stability of the dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Several items were noted during the visual inspection by the inspection team which should be monitored or controlled. Seepage along the spillway and discharge channel, and growth along the downstream face is of concern.

b. Adequacy of Information. Due to the inadequacy of engineering design data, the conclusions in this report were based on performance history, review of drawings and construction reports, and visual conditions. The inspection team considers that these data are sufficient to support the conclusions herein. However, seepage and stability analyses are needed to satisfy the requirements of Section 3.6.1 of the guidelines.

c. Urgency. A program should be developed as soon as possible to monitor at regular intervals the deficiencies described in this report. The remedial measures recommended in paragraph 7.2 could be accomplished now or delayed until observations of this monitoring program and/or the recommendation of a qualified engineer indicate the necessity of immediate action. If the safety deficiencies listed in paragraph 7.1a are not corrected, they will continue to deteriorate and lead to a serious potential of failure. Presently immediate action is not considered necessary.

d. Seismic Stability. This dam is located in Seismic Zone 1. Because stability analyses are not available, the seismic stability of the dam cannot be assessed.

7.2 REMEDIAL MEASURES

a. Alternatives. No measures are recommended.

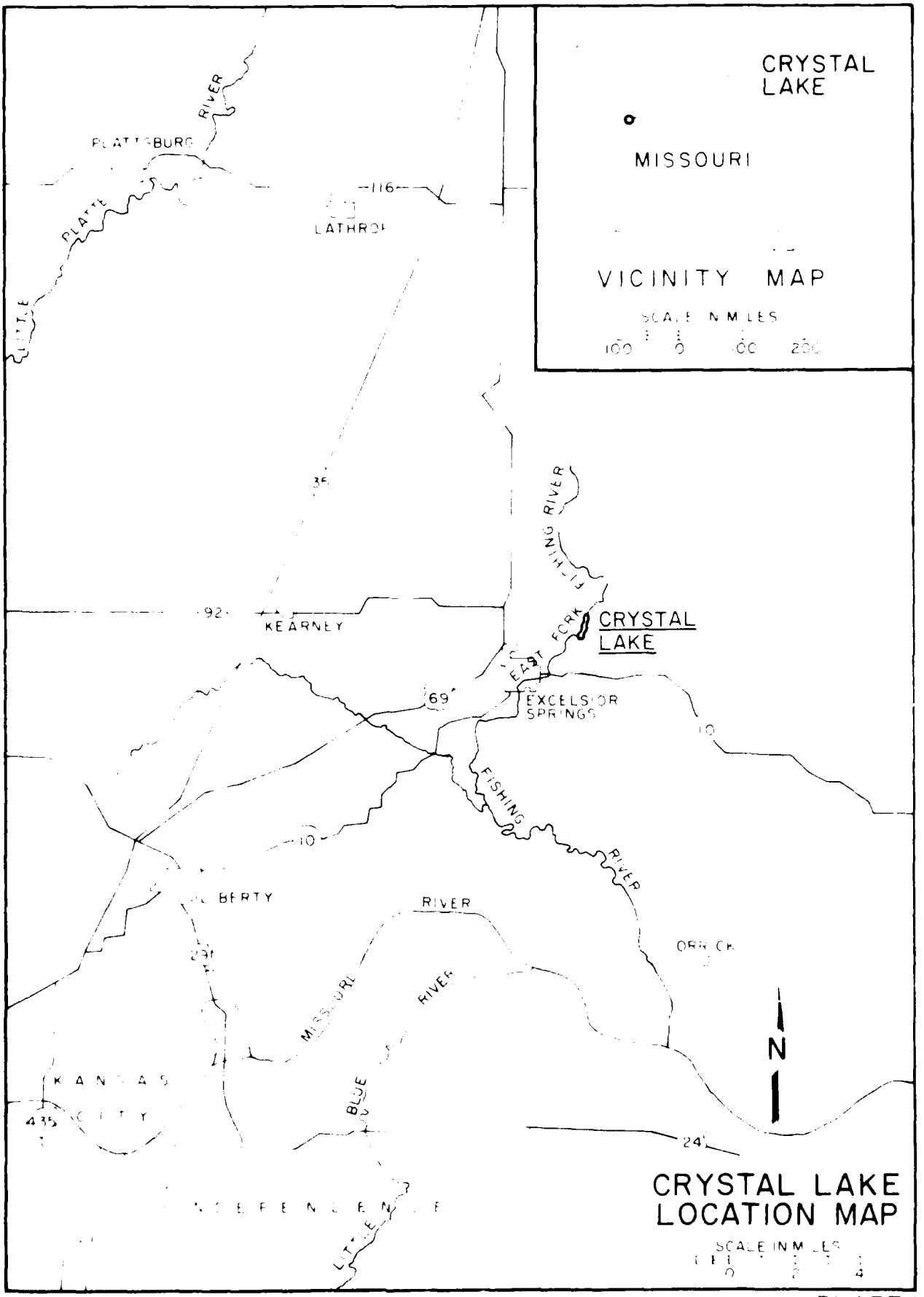
b. O&M Maintenance and Procedures. The following O&M maintenance and procedures are recommended:

(1) Check the downstream face of the dam periodically for seepage and stability problems. If increased seepage flows are observed or deterioration of the foundations of the embankment noted, the dam should be inspected and the pending condition evaluated by an engineer experienced in design and construction of earthen dams.

(2) Measures to curtail seepage along the spillway could be undertaken to minimize water loss.

(3) A regular maintenance program should be initiated to control the growth on downstream slope of the dam.

(4) A detailed inspection of the dam should be made at least every year by an engineer experienced in design and construction of dams. More frequent inspections may be required if items of distress are observed other than those already mentioned.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KEARNEY
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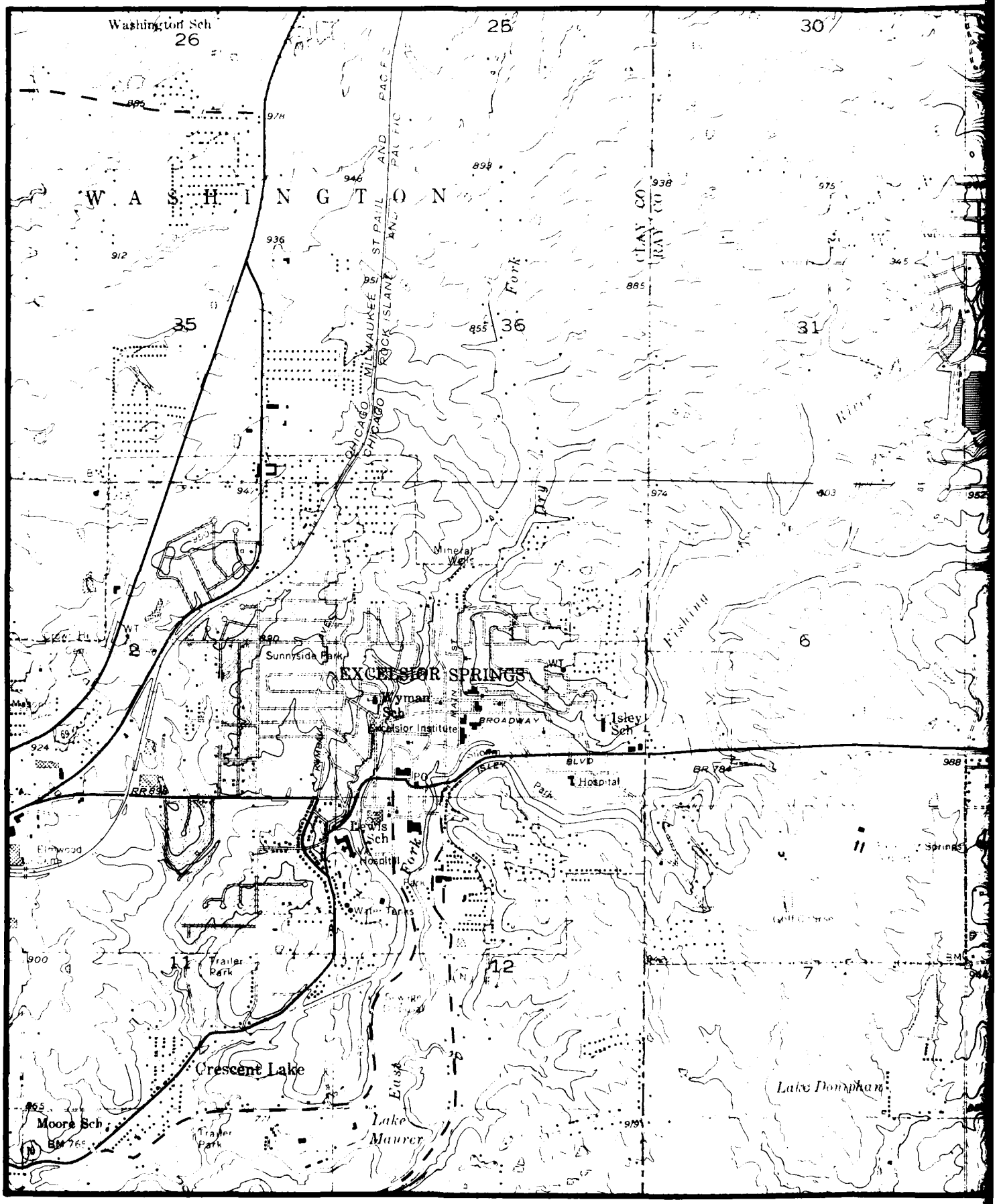
PLATE I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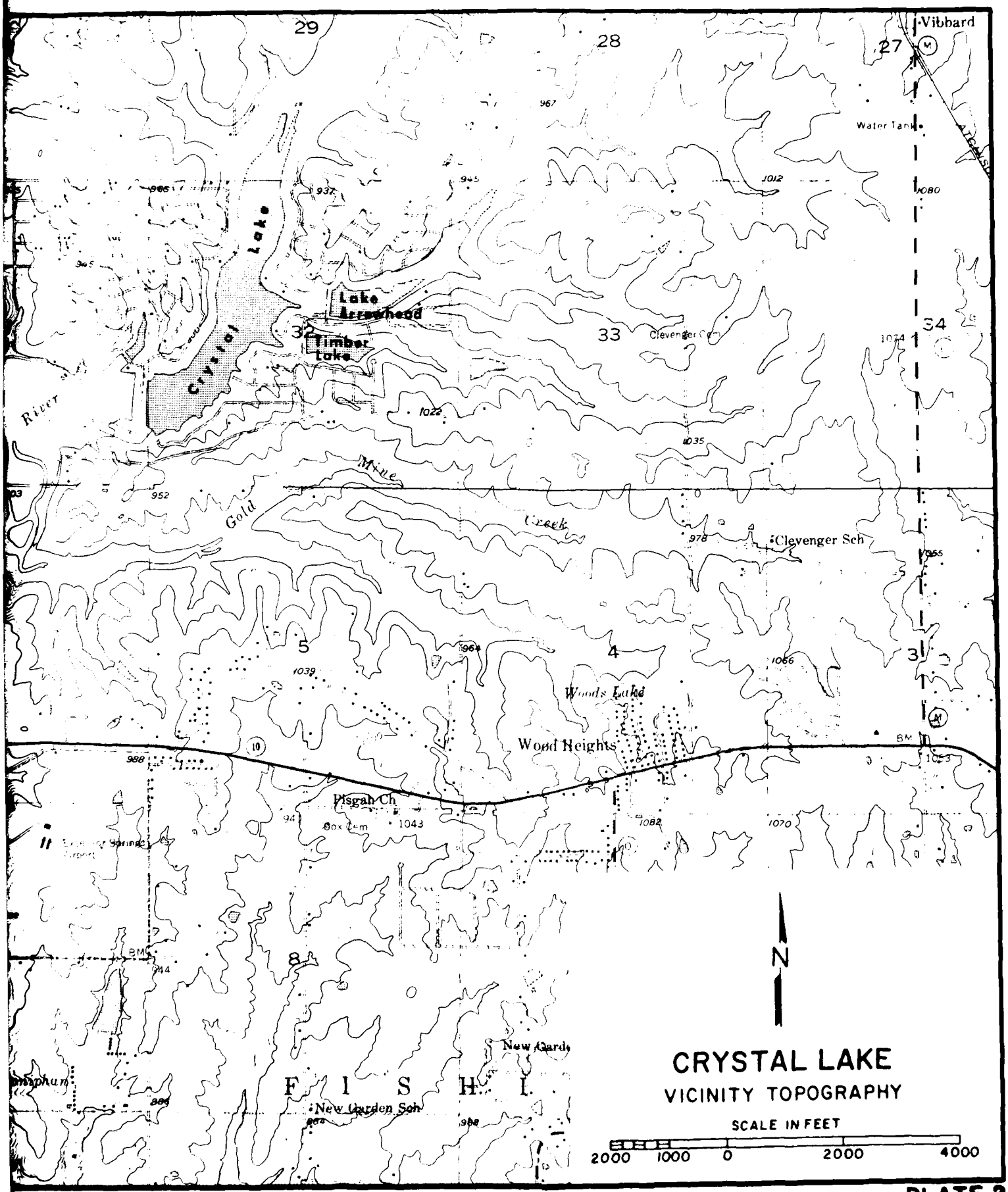
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VICINITY TOPOGRAPHY
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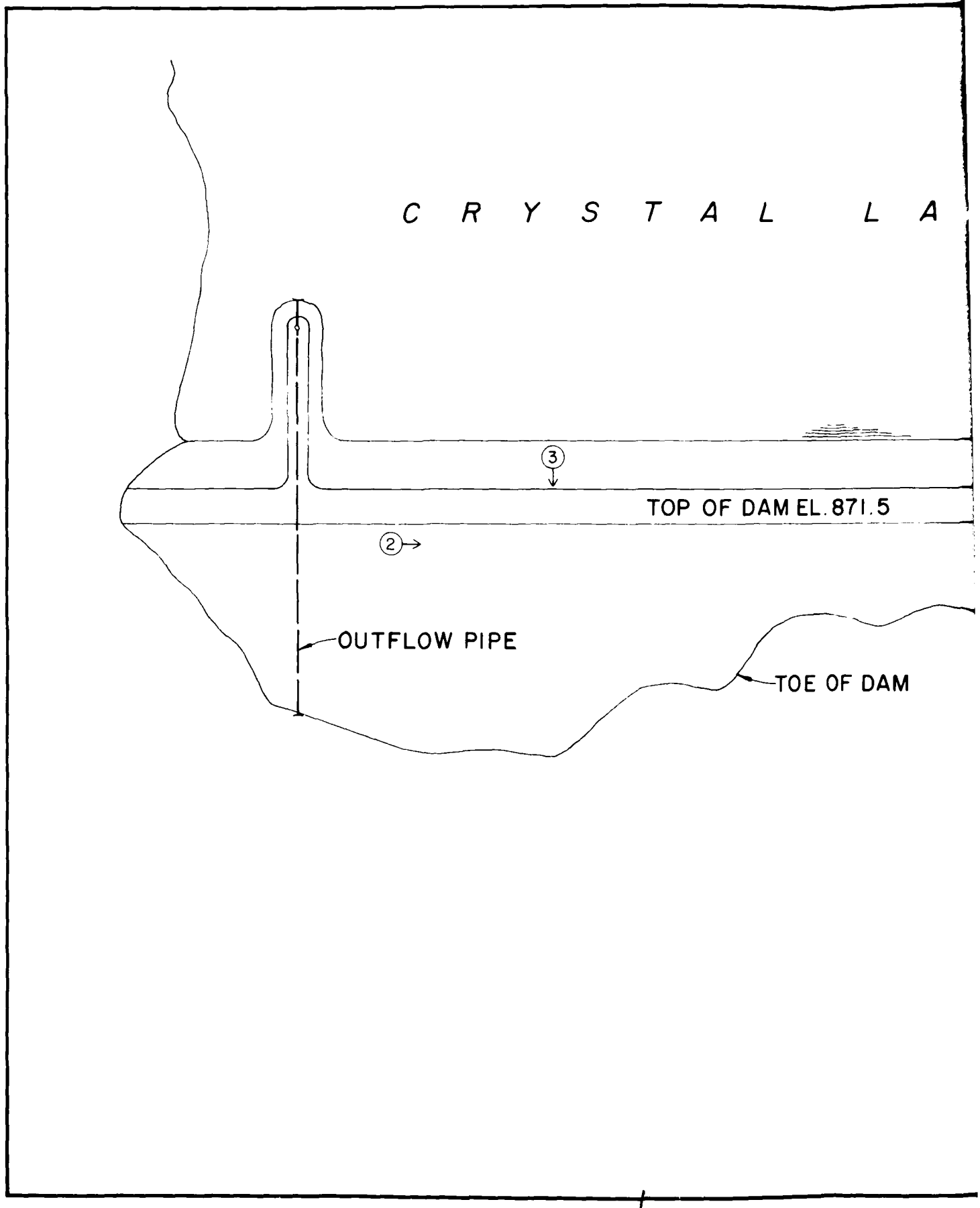
PLATE 2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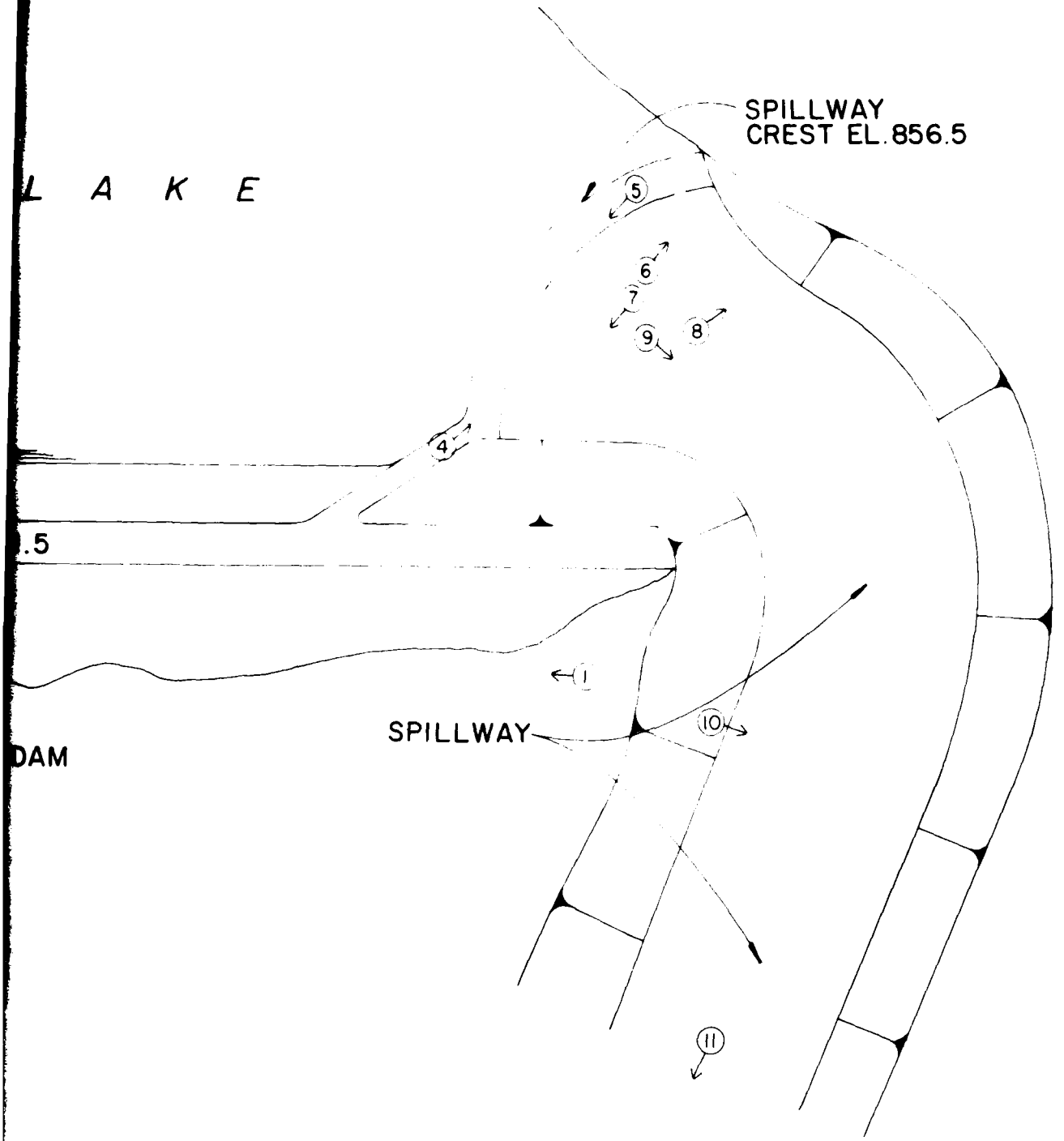
TOP OF DAM EL. 871.5
2
OUTFLOW PIPE
TOE OF DAM



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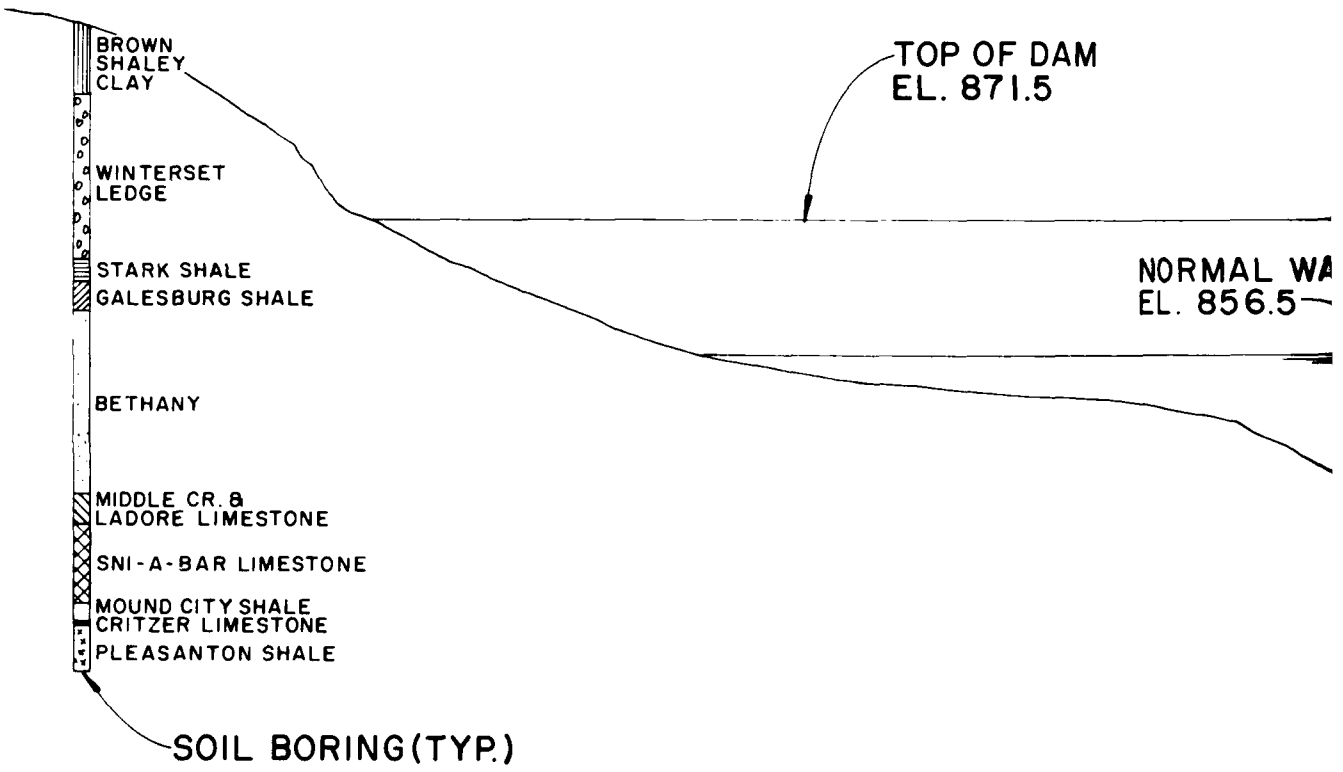
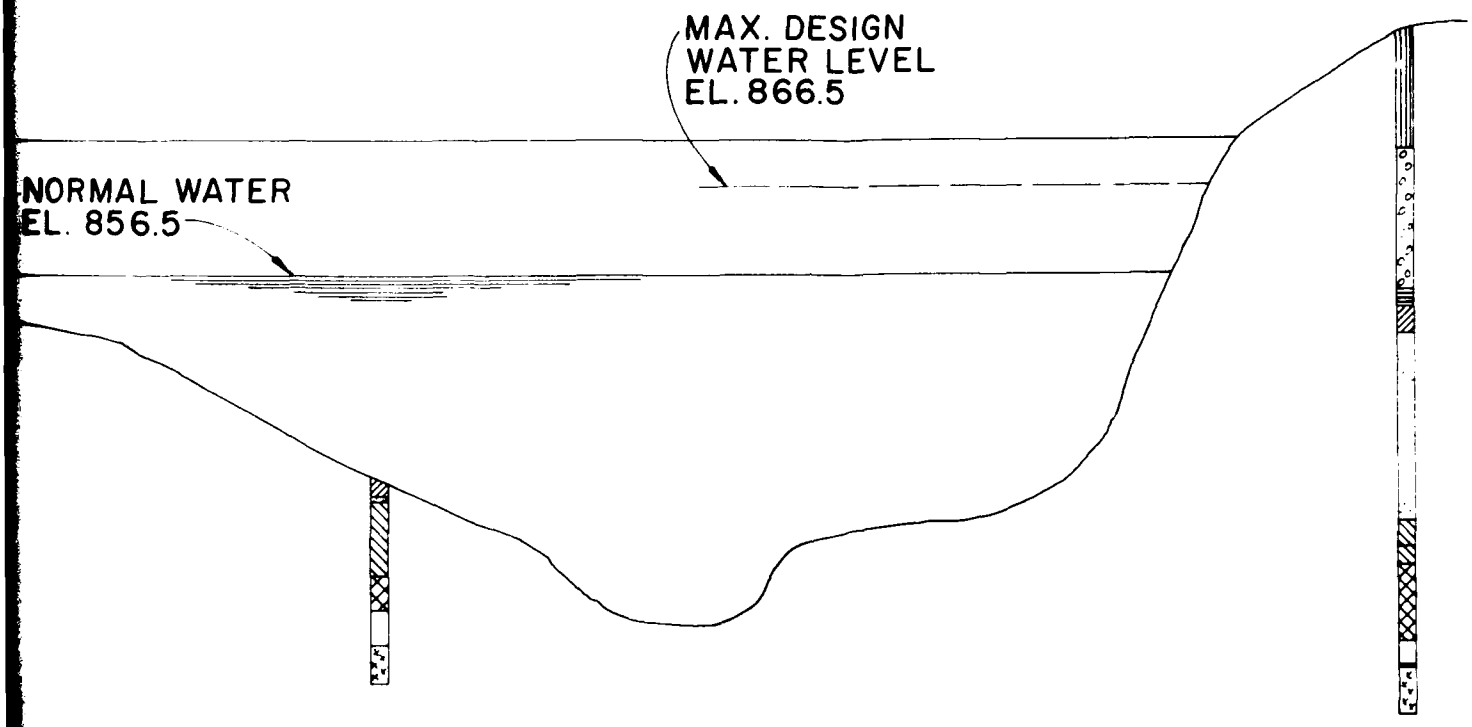
CRYSTAL LAKE
PLAN

PLATE 3



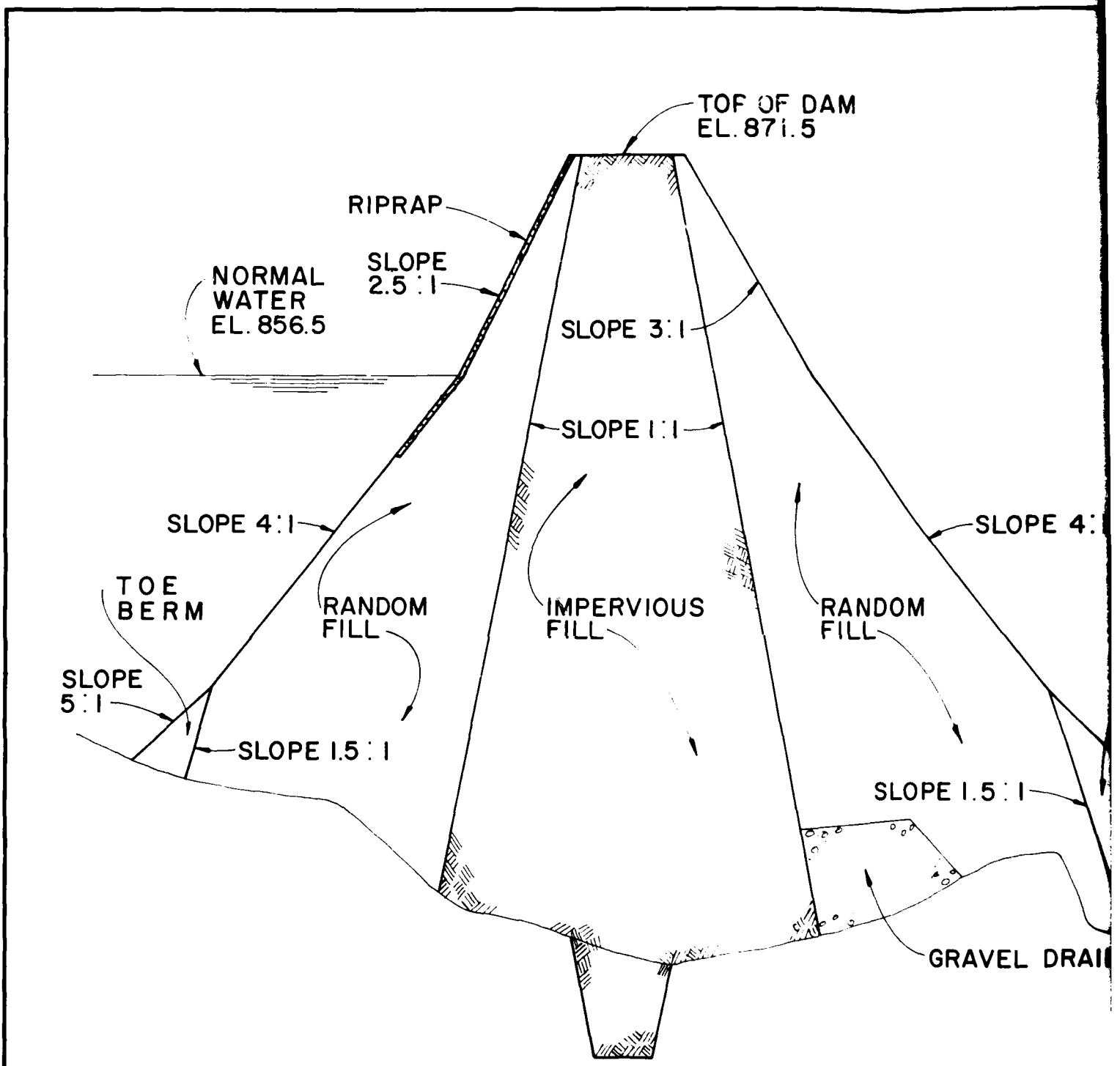
SECTION LOOKING



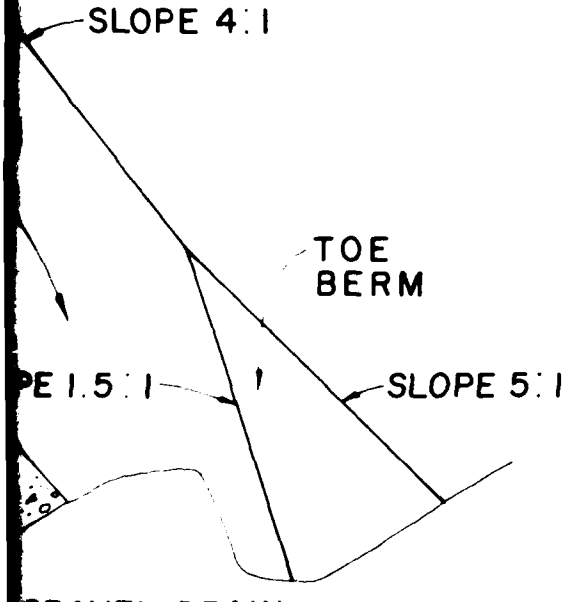
N LOOKING DOWNSTREAM

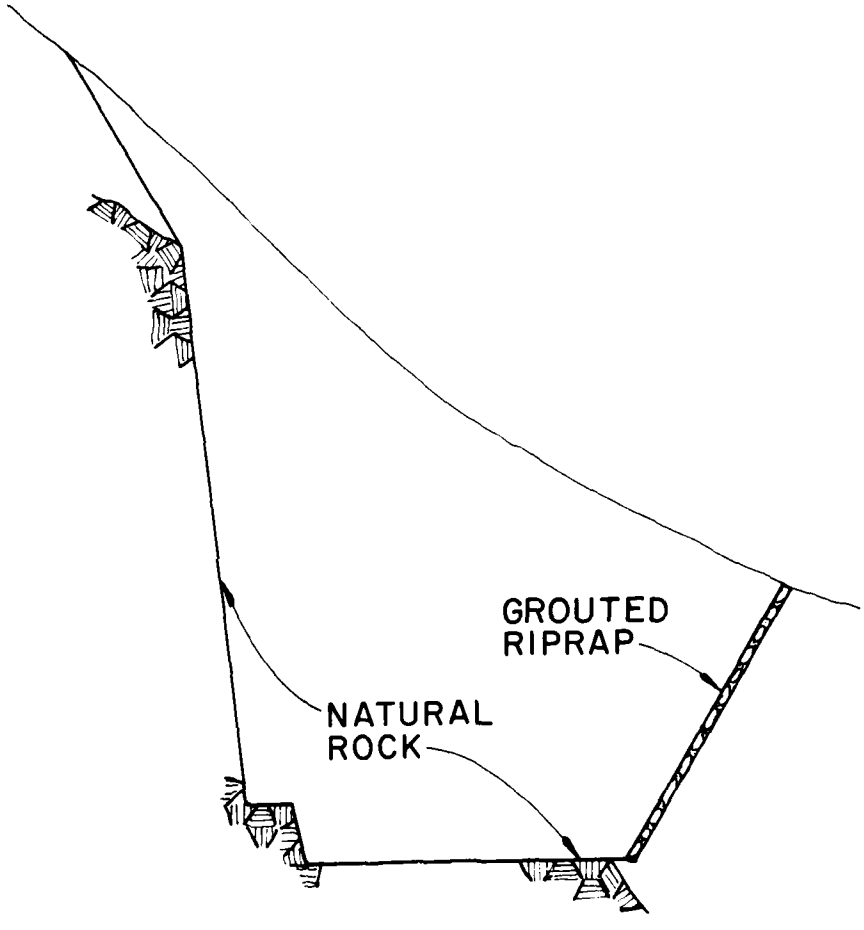
CRYSTAL LAKE
LONGITUDINAL SECTION

PLATE 4


TOP OF DAM
EL. 871.5
RIPRAP
SLOPE
2.5 : 1
NORMAL
WATER
EL. 856.5
SLOPE 3:1
SLOPE 1:1
SLOPE 4:1
SLOPE 4:
TOE
BERM
RANDOM
FILL
IMPERVIOUS
FILL
RANDOM
FILL
SLOPE
5 : 1
SLOPE 1.5 : 1
SLOPE 1.5 : 1
GRAVEL DRAI

D A M





S P I L L W A Y

CRYSTAL LAKE
TYPICAL SECTIONS

PLATE 5

PHOTO 1: DOWNSTREAM FACE OF DAM (LOOKING NORTH)

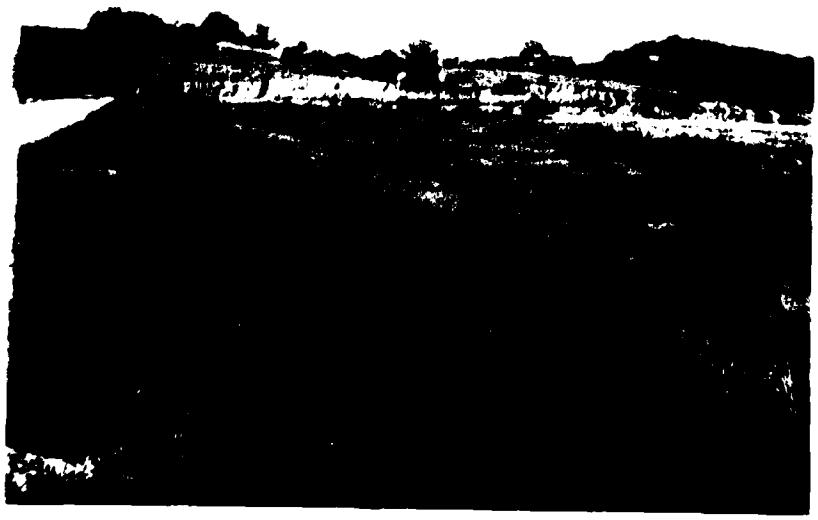


PHOTO 2: DOWNSTREAM FACE OF DAM (LOOKING SOUTH)

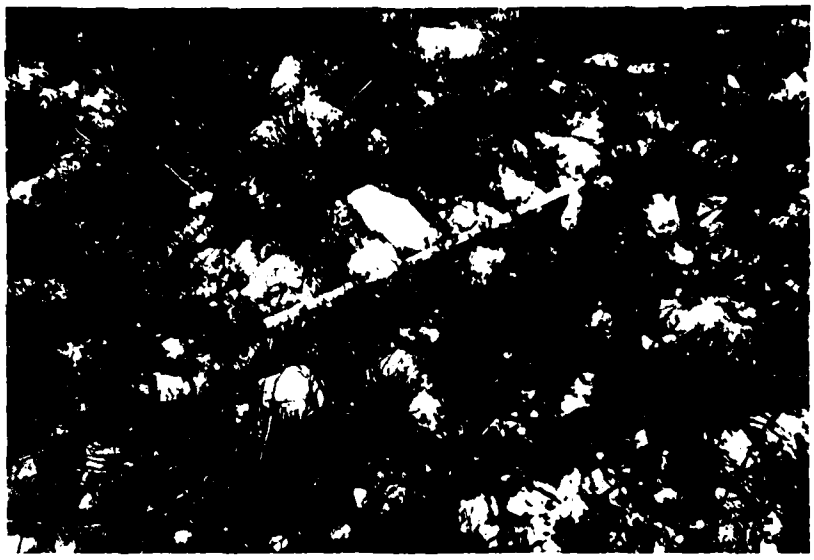


PHOTO 3: RIPRAP ON UPSTREAM FACE OF DAM

PHOTO 4: BROAD-CRESTED WEIR SPILLWAY (ROAD)

PHOTO 5: SEEPAGE AT WEIR AND ROAD JOINT

PHOTO 6: LEFT SPILLWAY TRAINING WALL (LOOKING SOUTH)

PHOTO 7: RIGHT SPILLWAY TRAINING WALL (LOOKING NORTH)

PHOTO8: LIMESTONE CUT IN SPILLWAY DISCHARGE CHANNEL (LOOKING SOUTH)

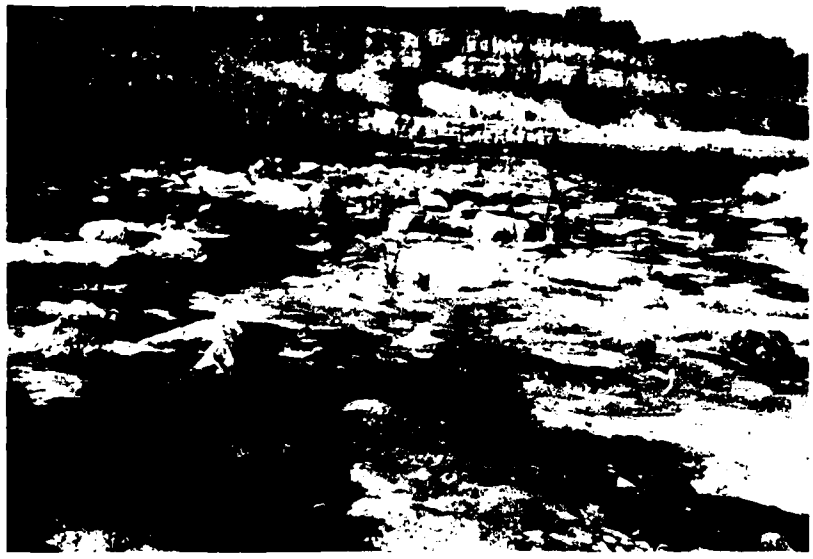


PHOTO 9: DISCHARGE CHANNEL IMMEDIATELY DOWNSTREAM OF SPILLWAY

PHOTO 10: LIMESTONE FALLS IN DISCHARGE CHANNEL

PHOTO 11: DOWNSTREAM CHANNEL

PHOTO 12: DOWNSTREAM CHANNEL

PHOTO 13: BRIDGE AND ROAD APPROXIMATELY 1 MILE DOWNSTREAM OF DAM

APPENDIX A

HYDROLOGIC COMPUTATIONS

HYDROLOGIC COMPUTATIONS

1. The Soil Conservation Service (SCS) dimensionless unit hydrograph and HEC-1 (1) were used to develop the inflow hydrograph (see Plate A-1) and hydrologic inputs are as follows:

a. Twenty-four hour, probable maximum precipitation determined from U.S. Weather Bureau Hydrometeorological Report No. 33:

200 square mile, 24 hour rainfall	- 24.6 inches
10 square mile, 6 hour percent of 24 hour 200 square mile rainfall	- 97%
10 square mile, 12 hour percent of 24 hour 200 square mile rainfall	- 116%
10 square mile, 24 hour percent of 24 hour 200 square mile rainfall	- 125%

b. Drainage area = 9,900 acres.

c. Time of concentration: $Tc = (11.9 \times L^3/H)^{0.385}$ = 215 minutes (L = length of longest watercourse in miles, H = elevation difference in feet) (2)

d. Losses were determined in accordance with SCS methods for determining runoff using a curve number of 88 and antecedent moisture condition III.

2. Spillway release rates are based on the broad-crested weir equation:

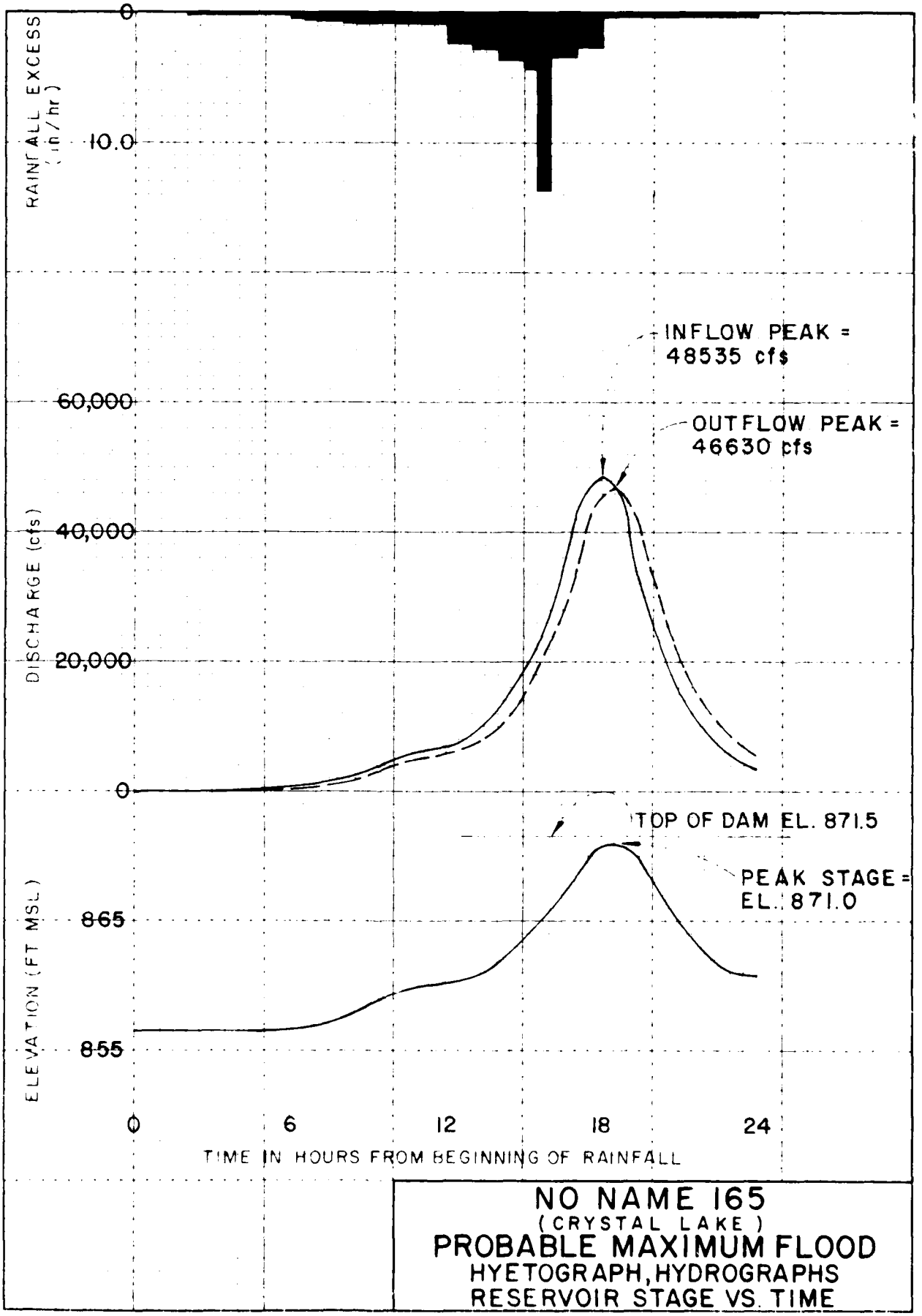
$Q = CLH^{1.5}$ (C = 2.8, L = 300 feet, H is the head on weir)

3. The elevation-storage relationship above normal pool elevation was constructed by planimetering the area enclosed within each contour above normal pool. The storage between two elevations was computed by multiplying the average of the areas at the two elevations by the elevation difference. The summation of these increments below a given elevation is the storage below that level.

4. Floods are routed through the spillway using HEC-1, modified Puls to determine the capability of the spillway. Inflow and outflow hydrographs are shown on Plate A-1.

(1) U.S. Army Corps of Engineers, Hydrologic Engineering Center, Flood Hydrograph Package (HEC-1), Dam Safety Version July, 1978, Davis, California

(2) U.S. Department of the Interior, Bureau of Reclamation, Design of Small Dams, 1974, Washington, D.C.



NO NAME 165
(CRYSTAL LAKE)
PROBABLE MAXIMUM FLOOD
HYETOGRAPH, HYDROGRAPHS
RESERVOIR STAGE VS. TIME

PLATE A-1